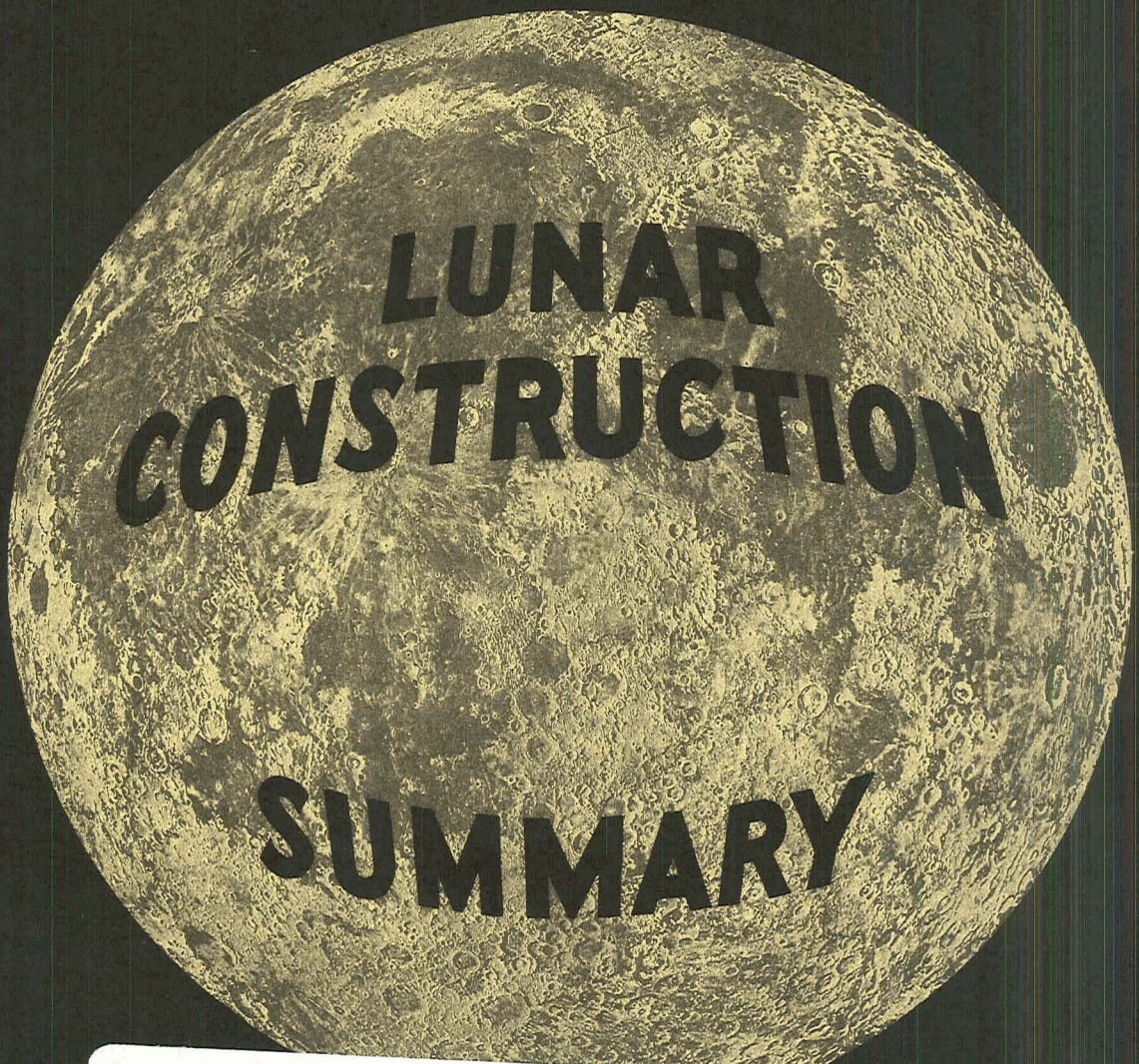
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OFFICE OF MANNED SPACE FLIGHT



LUNAR CONSTRUCTION SUMMARY

OFFICE OF THE CHIEF OF ENGINEERS
DEPARTMENT OF THE ARMY

APRIL 1963

#3

SUMMARY

SPECIAL STUDY OF THE RESEARCH AND DEVELOPMENT EFFORT REQUIRED TO PROVIDE A U. S. LUNAR CONSTRUCTION CAPABILITY

30 April 1963

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OFFICE OF MANNED SPACE FLIGHT

(NASA DPR W-11430)

Preliminary

By

THE OFFICE OF THE CHIEF OF ENGINEERS
DEPARTMENT OF THE ARMY
WASHINGTON 25, D. C.

SUMMARY

I INTRODUCTION

At the request of the National Aeronautics and Space Administration, the U. S. Army Corps of Engineers undertook a study, funded by NASA, to: define the research and development effort required to provide the United States with a lunar construction capability beginning in 1968; formulate the necessary technical development program; and recommend a detailed plan for program implementation, including definition of the experimental facilities needed. The results of that study are summarized below.

II PROCEDURE

The study was conducted in two phases. The first, completed in January 1963, resulted in an interim report primarily concerned with identification of elements of the technical development program in order to facilitate early consideration of FY 64 program requirements. The second involved a much more comprehensive analysis of the technical program - particularly problem areas - refinement of schedules and fund estimates, and development of a detailed plan for executing the lunar construction program.

In the study, current NASA planning and prior efforts by workers in this field were examined to develop the major areas of engineering application involved in attaining a lunar construction capability. Each was then analyzed in depth to determine requirements, evaluate these in terms of current state-of-the-art, identify specific research and development tasks and prepare detailed statements of methodology, effort, cost and facilities needed to accomplish such tasks. Particular attention was given to the capability of existing or planned terrestrial facilities to serve program needs.

Findings concerning the individual technical areas were then synthesized into a comprehensive technical development program integrated in time with current NASA thinking regarding manned lunar operations and associated lunar facility requirements. Available resources, related programs, restraints, and past experience in comparable Governmental research and development programs were related to the technical program and a plan for program implementation was drawn up representing the optimum combination of all factors involved.

Volume One of this report presents the background information, NASA planning and guidance, a summary of the technical development program and the plan - including schedules, costs, organization and facilities - for program implementation. Volume Two contains the individual technical engineering studies on which the comprehensive technical development program is based.

III LUNAR BASE CONCEPT

Fundamental to this study was a concept for a lunar base, to include a time-phased estimate of the types of facilities needed to support planned

operations on the moon. Guidance provided by NASA Headquarters included a modular base concept, the most up-to-date data available on the physical characteristics of the lunar environment, vehicle launch schedules and vehicle dimension and payload characteristics. As the study progressed, it was found necessary to make further assumptions within the framework of the planning data provided.

The basic concept developed envisions a family of modules of as few types as possible which can be combined in a variety of arrays to meet operational requirements. Both time and operational considerations dictate that only the most rudimentary construction capability be developed to support the Apollo landings; the Lunar Excursion Module (LEM) and its companion LEM Truck will supply life support needs. However, as stay times increase in the 1970-1972 period and lunar operations become more advanced, temporary bases with integrated life support systems will be necessary. Depending on additional knowledge gained by Apollo operations, these temporary bases may be expandable into semipermanent bases or a new generation of facilities may be required. These semipermanent bases, needed in the period 1973-1975, will evolve into permanent bases with more sophisticated and centralized support facilities.

Present lunar construction concepts depend on limited hard data and extensive assumptions regarding the characteristics of the lunar environment and the lunar surface material, particularly the latter. Ranger and Surveyor probes will provide much valid information on the composition of lunar surface materials but definitive data will not be available until man explores the moon. Notwithstanding this fact, most basic program requirements can be foreseen now and it is entirely feasible at present to map out a program and a plan for directing the actions necessary to develop a lunar construction capability in a timely manner. Such a program will clearly be subject to change in detail, but close control and built-in flexibility and responsiveness will minimize the adverse effects of such changes.

IV REQUIREMENTS

Current NASA thinking indicates the necessity for attainment of a lunar construction capability according to the following schedule:

Construction Capability	Time Period
Support for Apollo landings	1968 - 1969
Temporary bases, 6 man	1970 - 1971
Temporary bases, 8-12 man	1972 - 1973
Semipermanent bases, 12-18 man	1973 - 1975

To meet this schedule, two factors are critical. The first is a prompt start. The second is the timely acquisition of data on the characteristics of the lunar environment and lunar surface materials.

In addition to time schedules, lunar construction program requirements fall into several other general categories. There are performance requirements in terms of efficiency, simplicity, reliability and safety of systems and hardware items. The hostile lunar environment imposes a multitude of restrictions and requirements on the development of suitable construction methods, techniques, and materials. Finally, the restraints imposed by the resources available to the program and by vehicle configurations and launch rates introduce requirements affecting program planning and execution.

This study has considered requirements in those several contexts but its primary orientation, as an engineering study, has been on the technical engineering development effort necessary to develop a capability to construct lunar facilities. Necessarily included in the scope of the program are tools, equipment, materials, systems, subsystems, methods and techniques. Testing and demonstration of components, end-items and man-systems on earth are likewise essential elements of the program, as is training of those who will perform the construction operations on the moon. In general terms, the required technical effort is as follows:

Identify in detail the types of engineering works that must be built on the moon in the period 1965-1975.

Develop design criteria and construction methods for these lunar facilities.

Determine performance requirements for engineering materials, methods, processes and man-systems in the lunar environment.

Develop and test new materials, methods and processes as required.

Design and test on earth prototype structures and man-systems to the extent required to demonstrate their adequacy, limitations, and degree of reliability.

Determine the need for, and develop equipment, methods and procedures to accomplish maintenance and repair of engineering works on the moon.

Identify training requirements, develop training procedures, and train men who will build, operate and maintain lunar bases.

As mentioned, the technical engineering development program is based on a series of studies in each of the major engineering areas involved in lunar construction. The results of these were arranged into a coherent development program, with special attention given to those specific tasks which should be started in FY 64 to achieve a lunar construction capability in an orderly and timely manner. These tasks are in the fields of selenology, construction materials, excavation and surface modification, equipment, electric power and life support. Other tasks which should also be started in FY 64 are a lunar base study to refine and extend current base concepts, and terrestrial facilities design.

V PROGRAM EXECUTION

The study proposes a plan of action to implement the program requirements outlined above. As previously stated, the plan is considered to represent the best solution based on consideration of all pertinent factors. The plan, and the considerations used in developing it, are summarized below.

1. Management and Organization

Strong central management and close coordination with related programs are essential to the efficient and timely execution of the lunar construction program. This should be accomplished by a new staff element within NASA Headquarters. The mission and functions of this element will be substantially those of existing elements concerned with management of other programs.

A single field center should be responsible for detailed planning and execution of the program. Since technical program objectives largely involve a different field of engineering competence, a new field center is recommended, to be staffed and equipped for the sole and specific purpose of conducting the lunar construction program over the next 15 to 20 years or more.

To assure that the national space program benefits fully from all available Government resources, the extensive research and development staff and facilities of the Department of the Defense should be used in this program to the extent they can be made available. In this regard, agencies of the Department of the Army, particularly the Corps of Engineers, have developed a considerable degree of background competence related to such a program.

It is therefore proposed that NASA, in extension of the construction support already being rendered by the Corps of Engineers, utilize the capabilities of the Corps to establish, staff, construct, equip and operate the new field center. A formal working agreement would be executed between NASA and the Corps of Engineers defining the scope of the work and the channels of program coordination and control, and establishing policies and procedures. The center, called in the study the Extraterrestrial Engineering Center (EXTEC), would in effect be a NASA center, under the technical direction and control of NASA Headquarters but operated for it by others. The relationship between NASA Headquarters, OCE and EXTEC is illustrated schematically by Figure S-1. This proposal has not been coordinated with the Department of the Army or the Department of Defense.

2. Facilities

The study determined that a capability for integrated, real-time testing of man-systems in a simulated lunar environment, including the lunar surface material, is essential to the lunar construction development program proposed. It was further determined that no facility, existing or presently planned, will achieve that capability. Performance specifications and preliminary plans for such a facility, called the

Lunar Environmental Research and Test facility (LERT), were developed during the study. Sections and elevation views of LERT are shown in Figure S-2. An artist's concept of the large vacuum chamber contained in the LERT, in which the lunar environment will be simulated, is shown in Figure S-3. A number of ancillary facilities, including one for low-order simulation of certain lunar phenomena under ambient earth atmospheric pressure (the Operations and Training Building), are also necessary. Preliminary criteria, plans and cost data were developed in the study for all such facilities.

As a vehicle for facilities planning, optimum siting criteria were postulated and a reference site selected. That reference site is located in a southwestern state, it having been determined that that area of the United States offers the greatest potential for site selection favorable to technical program requirements. A typical layout for EXTEC based on the reference site, indicating the types of facilities required, is shown in Figure S-4.

3. Costs

The ultimate complete cost of developing a lunar construction capability cannot be estimated with reasonable accuracy at this time since the costs of suitable cargo and personnel delivery systems are beyond the scope of this study. In addition, the technical studies on which this report is based, while defining the planning, research, development and engineering effort required, did not attempt to make more than gross estimates of costs beyond FY 68. However, an order-of-magnitude estimate of total program costs, exclusive of purchase of operational hardware for use on the lunar surface, approaches $500 million.

Budget estimates through FY 68 were prepared during the study for major elements of the proposed program. These elements are:

Further study to refine and extend lunar base planning concepts

The technical engineering development program. This program was broken down and costed by specific tasks, with particular attention to those which must be started in FY 64 as a base for later effort

EXTEC facilities and Government furnished equipment (GFE) therefor

Personnel and operating costs

Program costs are summarized in the following tabulation:

	Fiscal Years ($ millions)				
	64	65	66	67	68
Lunar Base Study	.5	-	-	-	-
Engineering Development	4.7	24.0	57.3	102.4	59.7
Facilities and GFE	3.9	29.5	3.0	2.5	.5
Personnel and Operations	1.3	1.8	4.0	8.0	12.0
TOTAL	10.4	55.3	64.3	112.9	72.2

VI RECOMMENDATIONS

It is recommended that the National Aeronautics and Space Administration take the following actions before the end of FY 63:

1. Approve the study as a plan of action.

2. Initiate actions in the areas of organization, facilities and technical studies in accordance with the proposed plan of implementation.

3. Establish a site selection board for the new center.

4. Take action to secure and provide the funds required for the FY 64 program, including advance design funds for the new facilities.

5. Convene a joint NASA-OCE working group to draft a working agreement for this program.

FIGURE S-1

ORGANIZATION, LUNAR CONSTRUCTION PROGRAM

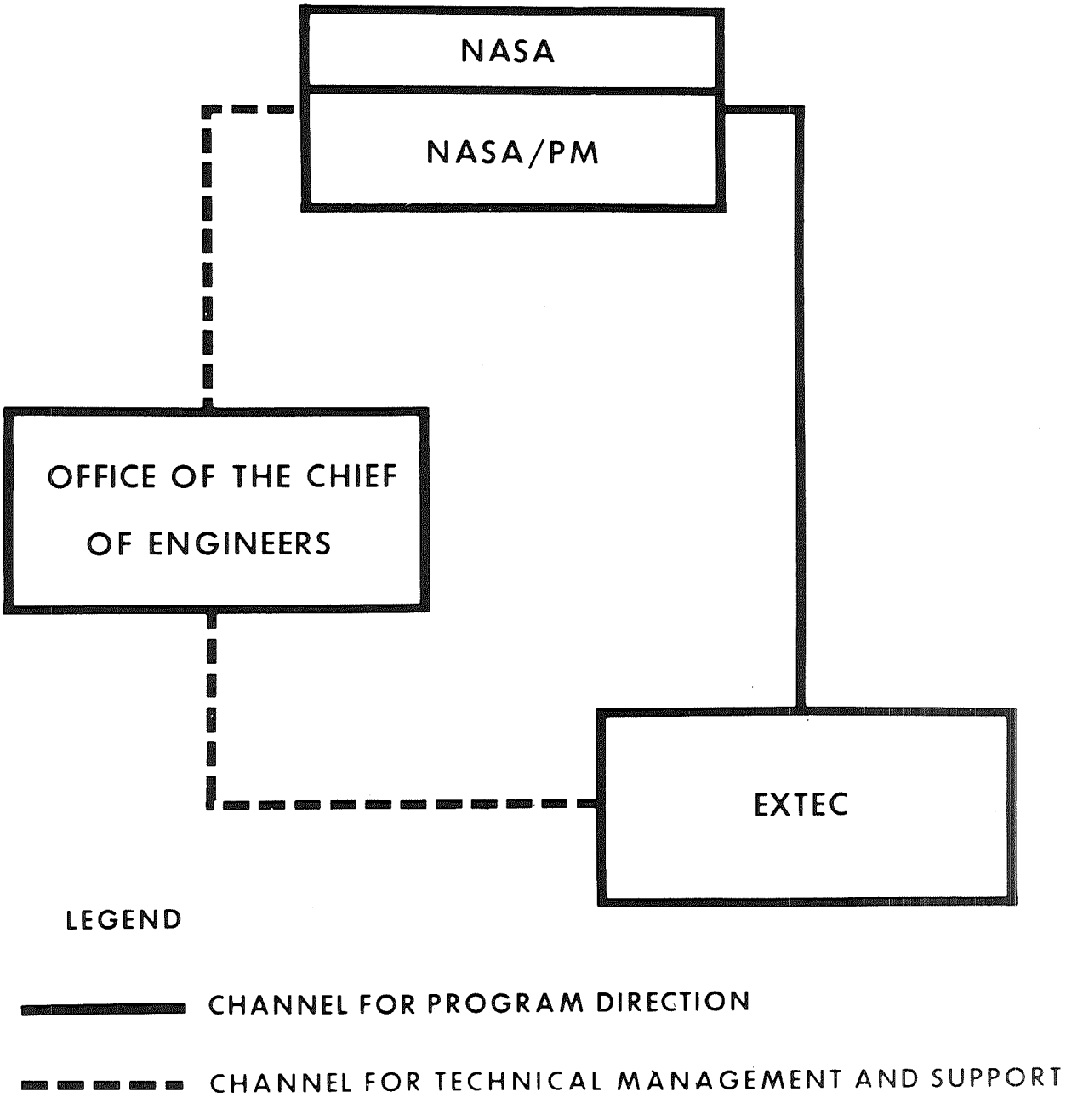
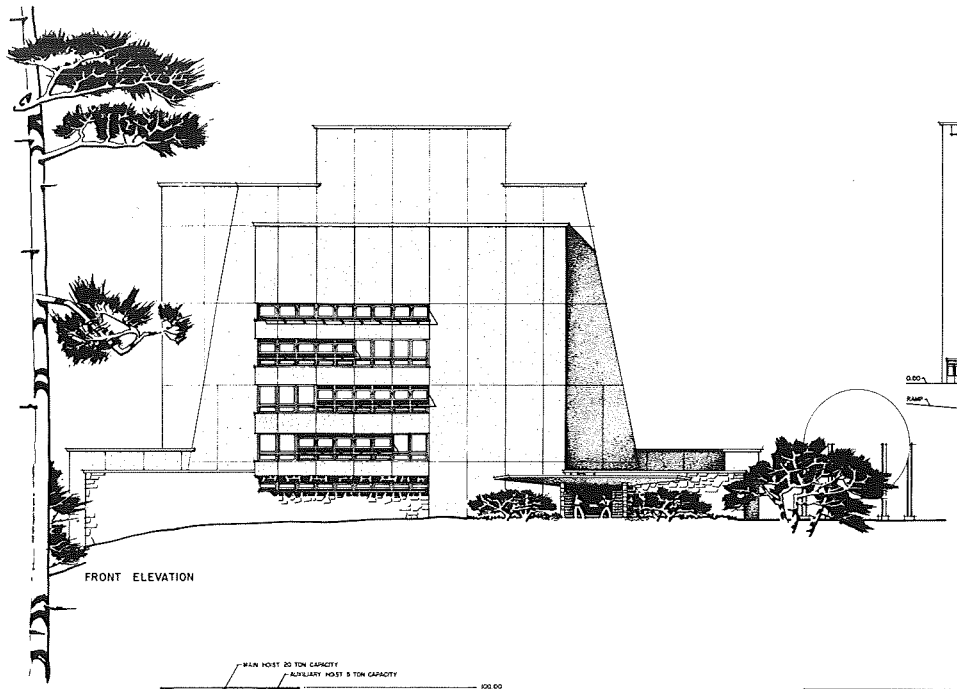
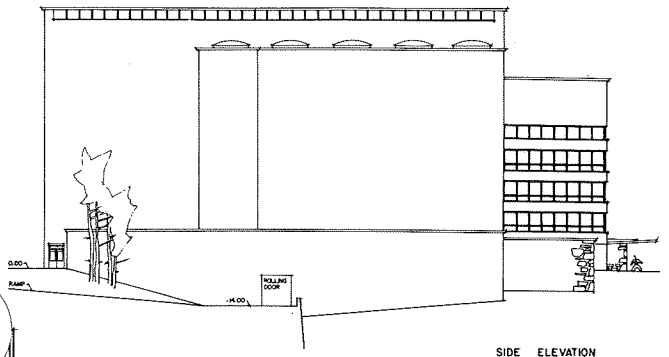


FIGURE S-2

LUNAR ENVIRONMENTAL RESEARCH AND TEST FACILITY - SECTIONS AND ELEVATIONS

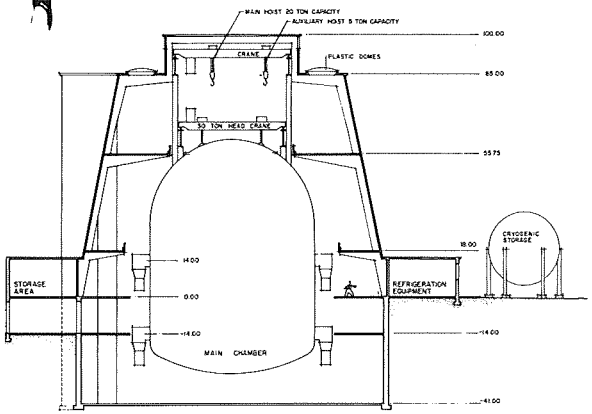


FRONT ELEVATION



SIDE ELEVATION

GRAPHIC SCALES



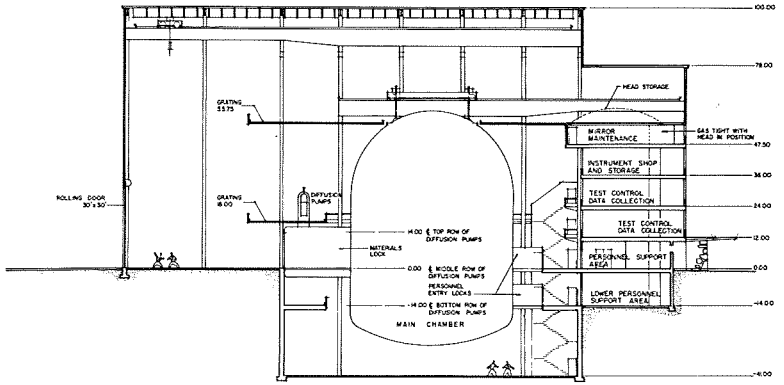


FIGURE S-3

LUNAR ENVIRONMENT SIMULATOR

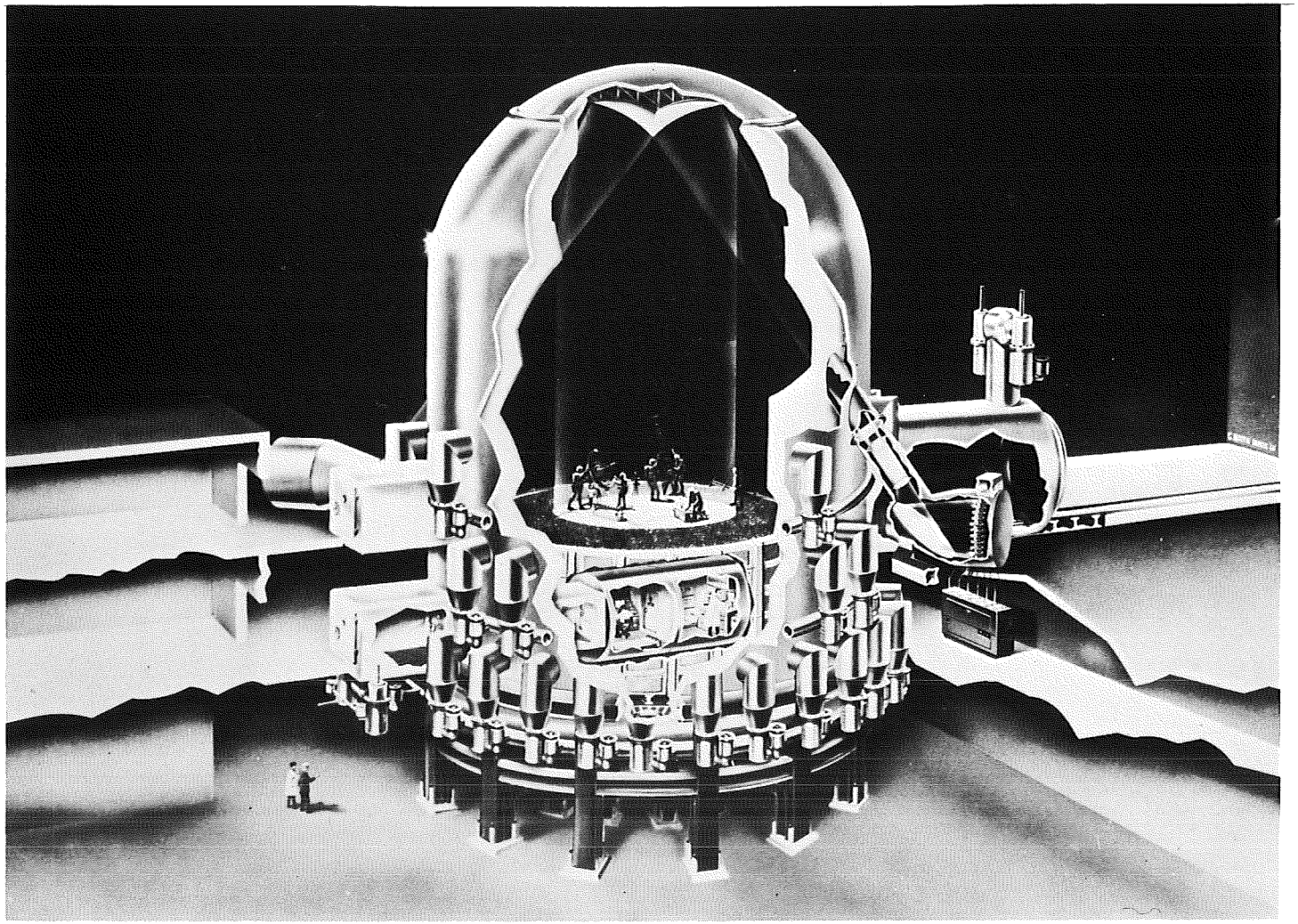
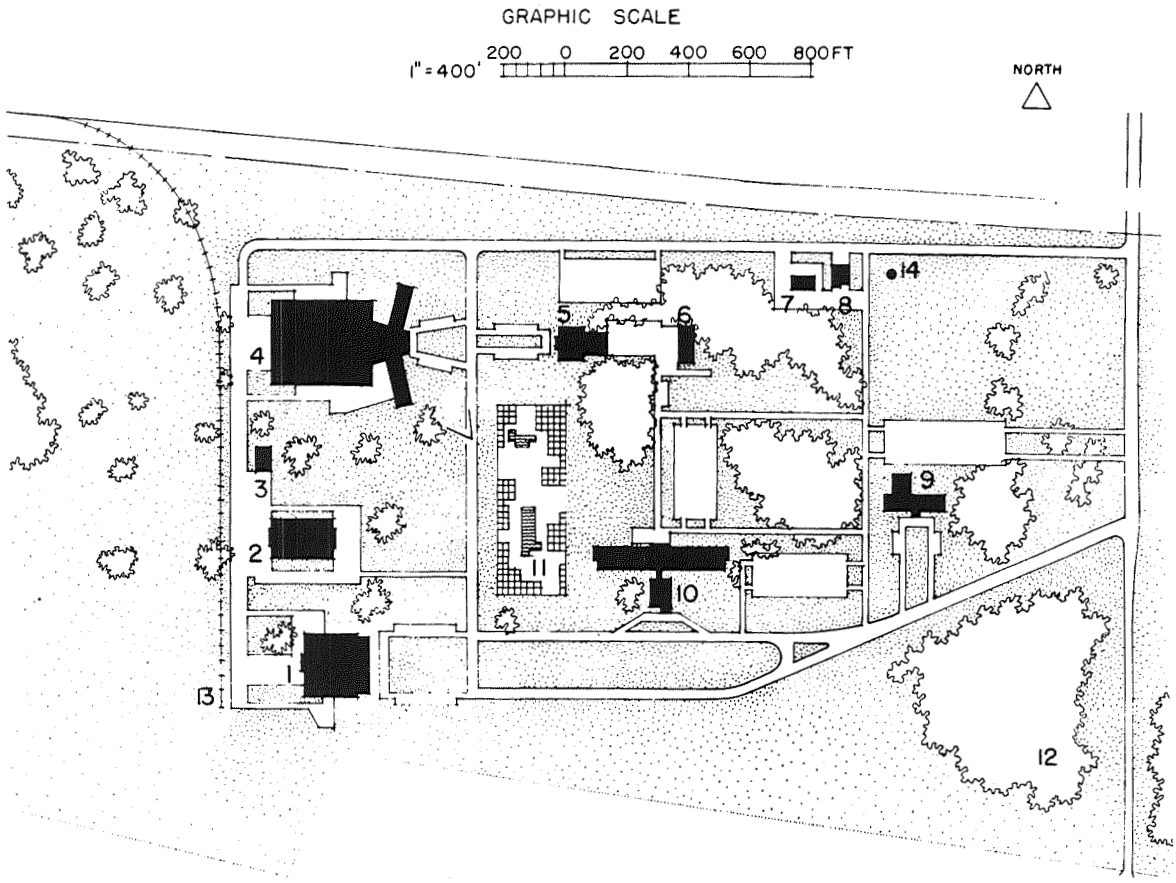


FIGURE S-4

EXTRATERRESTRIAL ENGINEERING CENTER
SITE PLAN



LEGEND

1 LUNAR ENVIRONMENTAL RESEARCH AND TEST FACILITY
2 ASSEMBLY AND PROCESSING BUILDING
3 DROP-TEST FACILITY
4 OPERATIONS AND TEST FACILITY
5 CAFETERIA
6 UTILITIES BUILDING
7 GARAGE AND TRANSPORTATION BUILDING
8 FIRE STATION
9 ADMINISTRATION BUILDING
10 ENGINEERING AND LABORATORY BUILDING
11 EXHIBITS AND DEMONSTRATIONS
12 INDICATES EXISTING TREE COVER ON SITE
13 R R SPUR
14 WATER TOWER